

station like Sitka. Everything considered, however, it is probable that on any scheme which assumed "activity" proportional to the square of the absolute range, the mean "activity" for December 16-17 would have been sensibly over-estimated at Kew, and considerably over-estimated at Eskdalemuir. On the other hand, the large difference between the values of A_1 and A_1' in Table IX, and the uncertainty this implies, shows that even with the elaborate procedure entailed by Bidlingmaier's full scheme, there is a large probable error at individual stations.

Under these circumstances a simple scheme, even if admittedly imperfect, deserves consideration.

A Method of Avoiding Collision at Sea.

By J. JOLY, Sc.D., F.R.S., a Commissioner of Irish Lights.

PART I.

(Received May 8, 1918.)

The following method of avoiding collision at sea depends on the use of synchronised signals, transmitted in different media. Such signals, travelling at different rates, enable the distance of their source to be inferred by observation of the gain in time of the faster upon the slower travelling signal. Thus, if signals be simultaneously emitted by wireless and by submarine bell (or Fessenden oscillator), the former being transmitted with practically infinite velocity, the latter arrive with a lag which is the time the submarine sound requires to traverse the intervening medium. The rate of propagation of sound in water being closely 4800 feet per second, the lag is 0.62 second for one-half sea-mile.

In practice the signals may be so ordered as to dispense with the stopwatch or chronograph. This is accomplished by sending out the wireless ticks in groups of, say, 20 "dots" spaced to intervals of 0.6 second. The stroke of the bell precedes the first of these dots by one of these intervals. Thus, when the sailor is half mile from the source he hears the first wireless dot along with the bell stroke. If he is 1 mile distant the bell stroke comes in with the second dot, and so on. He has, in fact, only to count up the dots till he hears the bell, and the number of the dot coincident with the bell is the number of half sea-miles intervening between his ship and the source of the signals. It is possible to estimate the quarter mile by noting a want

of coincidence between bell stroke and dot. This method of estimating distance is in actual operation in assisting mariners to navigate the approach to New York Harbour, the signals being emitted from the Fire Island Light Ship. It is of special value in coastal navigation.

I shall assume that readings can be effected no more accurately than described above—although more exact and yet practical methods of determining the lag of the sound wave are probably feasible. In what follows, however, the reading to the quarter sea-mile will be assumed as the limit of accuracy attainable, in determining the distance between ship and ship. The emission of the signals may be entirely automatic, a mechanically driven contact maker accurately spacing the signals. This would be in charge of the wireless operator on board, and in fog, thick weather, or darkness, would be set in operation according to (future) Board of Trade regulations.

In the successful working of the method now to be described these synchronous signals are all sufficient. The groups of signals might be spaced half a minute apart. That is at the beginning of each half minute the emission of 20 wireless dots of such low power as to avoid unnecessary distance would be commenced. The group would finish in 12 seconds. There would then be a pause of 18 seconds, when a second group would be started.

I have already suggested a method* based on synchronised signals, and involving a knowledge of the course and speed of each ship; each vessel transmitting by wireless code to the other ship information as to her own course and speed. The present suggested method does not involve this knowledge, nor any other communication between the ships beyond the synchronised signals described above.

The rate of mutual approach of ships which are moving so as to collide is constant and remains so to the moment of collision. If they are advancing so as to pass clear, the rate of mutual approach diminishes as the vessels draw near one another, becomes zero when the vessels are at the least distance apart, and then becomes negative. I shall assume for simplicity of treatment that the relative velocity of the ships is transferred entirely to one of the ships, which I shall call B, the other ship, A, being stationary. The suggested method of avoiding collision involves the discrimination of what may be called the constant danger rate of approach from the variable rate denoting safety.

Let the initial distance of B be 10 nautical miles or knots. The sailor on A is not aware of the bearing of B. He detects her synchronised signals (which at such a distance would be those of a Fessenden oscillator and low

* 'Roy. Soc. Proc.,' A, vol. 92, p. 252 (1916).

power wireless), and observes the decrease in the distance of B indicated by the successive signals. His primary and essential purpose is to ascertain if there is a diminution in this loss of distance, as shown by succeeding signals.

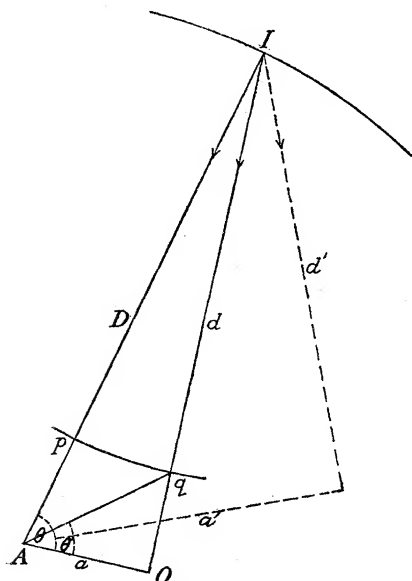


FIG. 1.

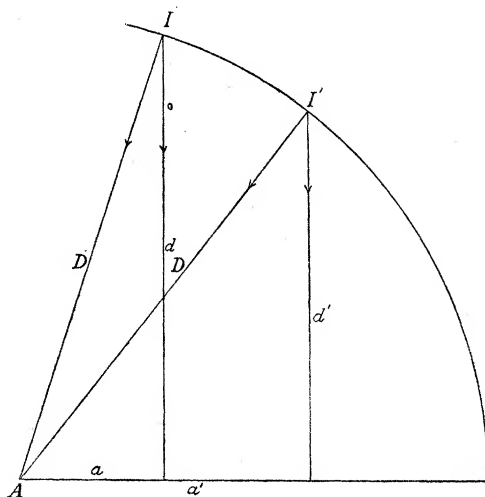


FIG. 2.

A may be regarded as placed in the centre of a circle of, say, 10 miles radius, upon the circumference of which B is somewhere placed; say at I. Then, if D is the radial distance of B from A, D is the danger course of B. Let d be an alternative course of B which passes clear of A at the minimum distance, or clearance $AO = a$. Then a is perpendicular to d , and $a \sec \theta = D$. Assuming some value of a , the angle θ is known, and $d = a \tan \theta$.

B may be advancing along D or along d . The sailor can discriminate between these courses when B has moved a distance $Ip = Iq$ from the initial point I, such that he can detect with certainty a difference in the distance of B according as to whether she is at p or at q . For if B is on the danger course, Ap is the residue of the 10 miles; if she is on the safety course her distance must be greater than Ap . B at successive instants is all along further from A on the safety than on the danger course. The point q is such a point as permits this fact to be estimated by the synchronised signals. Now $qO = d - Ip$; and $qO/a = \tan \theta'$; giving θ' . Then $Aq = a \sec \theta'$. Accordingly the comparison is between the distance Ap and $a \sec \theta'$.

It is evident that with increasing values of a the difference between Ap and $a \sec \theta'$ increases, the latter distance, for a given value of Ap , increasing

as θ' diminishes. The discrimination between safety and danger can, therefore, be effected at an earlier moment for a wide clearance of A and B than for a "close shave."

I have described the most general case where the course of B may radiate from the initial point I in any direction such that she tends to approach A. This construction holds till a becomes equal to D, when her course is tangential to the circle at I, and she continues all the time to recede from A.

The various courses which may be run by B as radiant from I, such as d or d' , fig. 1, may also be considered as initiated at points on the circle so placed that the nearest approach to A is measured along a common radius, as in fig. 2. The distances shown by the successive signals will be the same in this as in the more general case for any given value of a or θ , but the compass bearings of B from A will be different in the two cases. In short, it is evident that the triangle IOA may be supposed rotated into any position round A; the problem remains essentially the same.

The following Table shows the distance of B from A corresponding to the danger or direct distance shown in the first column. The successive columns after the first refer to various values of a , or the least passing distance between the vessels. The initial distance is taken as 10 miles.

Table I.—Danger and Safety Distances (Initial Distance 10 Miles).

Danger Distances.	Safety Distances : Miles.						
	$a = \frac{1}{2}$.	$a = 1$.	$a = 2$.	$a = 3$.	$a = 4$.	$a = 5$.	$a = 6$.
miles.							
8	8·0	8·01	8·05	8·11	8·21	8·33	8·49
6	6·00	6·03	6·13	6·30	6·53	6·83	7·21
5	5·00	5·05	5·20	5·44	5·77	6·20	6·71
4	4·02	4·07	4·30	4·64	5·10	5·66	6·32
3	3·03	3·11	3·44	3·93	4·55	5·27	6·08
2	2·02	2·19	2·69	3·37	4·16	5·04	6·00
1	1·11	1·38	2·15	3·05	4·00		
$\frac{1}{2}$	0·70	1·10	2·02	3·00			
$\frac{1}{3}$	0·59	1·04	2·00				
$\frac{1}{4}$	0·55	1·02	2·00				

At a passing distance of $\frac{1}{2}$ mile B must approach A to within $\frac{1}{2}$ mile measured on the radial or danger course, before any indication of her real course would be obtained. At $\frac{1}{2}$ mile distance the danger and safety distances differ by 0·20 mile. This is nearly $\frac{1}{4}$ mile, and some indication of want of coincidence in the signals would be detected by an experienced observer. At $\frac{1}{3}$ mile the increase of distance on the safety course is more than $\frac{1}{4}$ mile, and should also be detected. At $\frac{1}{4}$ mile the difference is

0.30 mile, and the want of coincidence in the signals could not be missed. We may say, then, that, given a reliable transmitting apparatus, timing the signals with accuracy (a condition perfectly attainable), and a careful observer, alert and practised in listening to such signals, there should be no need to alter course for a passing distance of $\frac{1}{2}$ mile. I describe further on certain aids towards accuracy, which should render this quite certain.

Looking to the next column, giving the distances for the course passing at 1 mile from A, we see that already at 2 miles there must be want of coincidence in the signals, and at 1 mile this must be quite conspicuous. At $\frac{1}{2}$ mile the sound signals are displaced by one radio dot, and only an error in the count could lead to its being overlooked. The aids towards accuracy just referred to will be found to eliminate the possibility of this error, the counting being rendered unnecessary.

Looking along the successive columns of the Table, we perceive that the difference between safety and danger becomes ever more conspicuous, and may be detected earlier as the value of the passing distance a increases. With a passing distance of 2 miles, when the ships are 3 miles, or even 4 miles, apart, the fact of safety should be apparent. At 1 mile apart the difference between danger and safety increases to two radio dots. For 3 miles passing distance two radio dots measure the difference of safety and danger at 2 miles, and so on.

If we plot these results, the distances, as determined by synchronous signals, being taken as ordinates, and the danger distances or successive units of time as abscissæ, we obtain the group of curves shown in fig. 3. The diagonal right line is the curve for danger. Above it, and ever more differentiated from it, lie curves for increasing values of a . The slope of the danger curve—*i.e.* the rate of approach or relative velocity—is constant for this line only. In the other curves the relative velocity diminishes, first slowly, then more rapidly, and finally decreases to zero, when the curve becomes parallel to the axis of x .

It is evident that, if the sailor plots his observations, he would obtain one of these curves, the precise slope at any point depending upon the value of a and the relative velocity of A and B.

We have considered the case of the signals of B being first heard at a considerable distance from A. As B draws near, the divergence between the danger course and the safety course separates more and more the two possible loci of B. When, therefore, B has travelled some considerable distance from the initial point, say 2 miles, the value of $a \sec \theta'$ attains a certain excess above the value of $D - Ip$. In this excess the discrimination of safety and danger is founded. But, suppose, now, that the distance at

which the ship B is first heard is considerably less than 10 miles, say 5 miles, we have to ascertain if a mile run either on danger or safety

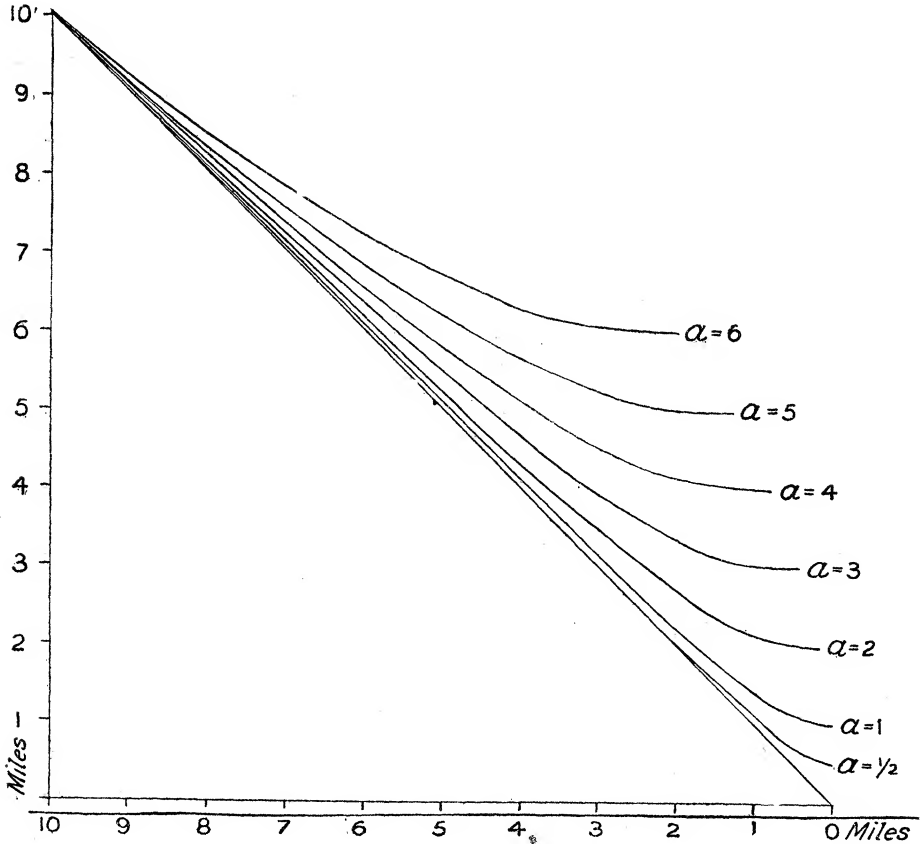


FIG. 3.—Safety and Danger Distance.

course (keeping the same value of a) affords an equally good basis for discrimination between the courses. There is, in fact, a certain loss of discriminating distance in this case. The following Table (II) assumes an initial distance of 5 miles and various values of a . If we compare this with Table I, we see that the excess of safety over danger distance is less, although not much less. Five miles may be taken as a fair value for the initial distance where submarine bell is used. But the initial distance might be even less. Table III, calculated for a value of a of 1 mile and initial distances of 10, 6, and 3 miles, shows that there is but little difference when a is small. The reason for the difference attending greater and lesser initial distances may be most briefly referred to the fact of the lesser separation of the danger and safety loci for a given run on the two possible

courses when the start of B is supposed to be close to A. At increased values of a this effect is diminished.

Table II.—Danger and Safety Distances (Initial Distance 5 miles).

Danger Distances.	Safety Distances : Miles.			
	$a = 1.$	$a = 2.$	$a = 3.$	$a = 4.$
miles.				
4	4·03	4·10	4·24	4·47
3	3·07	3·27	3·61	4·12
2	2·15	2·55	3·16	4·00
1	1·35	2·08	3·00	4·12

Respecting large values of a , it will be apparent that these insure in all cases an early discrimination between safety and danger. For the observation must then reveal at an early stage, and while there is still a large separation between the vessels, the fact of safety by attainment of the zero rate of approach. We are therefore, in judging the value of the method, more concerned with the discriminating distances for small values of a than for large.

Table III.—Influence of Initial Distance ($a = 1$ mile).

Danger Distances.	Initial Distances.		
	10 miles.	6 miles.	3 miles.
miles.			
6	6·03	6·0	
4	4·07	4·04	
2	2·19	2·16	2·08
1	1·38	1·36	1·30
$\frac{1}{2}$	1·10	1·08	1·05
$\frac{1}{4}$	1·02	1·01	1·00

From the foregoing Tables it is, I think, evident that a practical method of avoiding collision is to be found in the simple observation of distances separating the vessels. The method possesses the very great advantage over the old method by observation of bearing, that the distance separating the ships, which is the really important element in all cases, is being watched throughout in the mere taking of the observations.* We have to

* *Note added in the Press.*—Observation on A of ordinary sharp sound signals emitted by B at uniformly spaced, regulated intervals, would suffice to determine, by Döppler's principle, whether the ships were receding from, or approaching, one another; an estimate of the relative velocity could be made, and it could be ascertained whether this

consider now how the method may best be applied so as to diminish the danger of errors and increase its sensitiveness so far as practicable.

There is no doubt that a practised operator would readily estimate the distances to the $\frac{1}{4}$ mile by simply counting up the radio dots and observing whether there was coincidence between bell stroke and dot, or whether the former fell between the successive dots.

A suitably designed stop-watch would, however, afford him much aid, and effectually guard against errors of counting. This stop-watch would carry a central hand, which completed a rotation in exactly $\frac{1}{2}$ minute, or, for a more open scale, $\frac{1}{4}$ minute. The number of its revolutions, and the minutes or half-minutes, are recorded on a smaller dial. The operator starts this watch into action on hearing the first radio dot of a group. Thereafter, the watch keeps time with the emission of signals on the other ship. This is no great demand. The instruments for sending out signals would, of necessity, be standardised under proper supervision.

As the watch keeps time with the emission of the signals on B, it is evident that the operator on A has only to listen for the bell stroke, and read on the watch dial the instant at which they reach him. To enable this to be done, the watch carries the usual stop-hand, which moves with the central timing hand, and is stopped by the operator on hearing the bell. It then shows on the dial the position of the timing hand when the bell was heard. The dial is divided into divisions corresponding to the time taken for the travel over $\frac{1}{2}$ sea-mile of the sound in water.

Thus the whole circumference would be divided into about twenty-five parts, of the value of 0.6 second each, and these would be again subdivided into four or five parts, *i.e.* reading $\frac{1}{8}$ or $\frac{1}{10}$ mile separating the vessels. A numbering showing sea-miles and $\frac{1}{2}$ sea-miles is carried round the dial. On the release of the stop-hand it returns to zero, and automatically starts afresh when the timing hand begins a fresh revolution. It will be seen that the operator's duties, in taking in the signals, consist (*a*) in starting the watch, by the first radio dot of a group, into unison with the signals emitted by B, and (*b*) in pressing the stop and reading the dial when the bell strokes come in.

In order to apply his readings to the discrimination between safety and danger, he has before him a paper pad or card ruled with a fine, sharp, diagonal line sloping downward from left to right. This line is the danger

velocity remained constant or varied. Thus, if the relative velocity was 24 knots, B approaching, sounds in water emitted every 60 seconds by B would appear to observation on A to be spaced 59.5 seconds. This system, however simple it may appear, is under the grave disadvantage of leaving the distance between the vessels indeterminate.

line. A horizontal axis beneath is divided into centimetres and millimetres, and the centimetres are numbered from right to left. A vertical scale is carried on the edge of a T-square, which moves across the pad, in guides, so that, when moved, the points on the edge of the T-square describe lines accurately parallel with the horizontal. The divisions on the edge of the T-square are numbered to correspond with the numbering on the dial of the watch, *i.e.* for miles and fractions.

When the first distance is read on the stop-watch the T-square is shifted till the corresponding point is upon the sloping line. The second distance obtained by observation is treated in the same manner; the ordinates being ruled on by pencil. There is now a certain horizontal spacing proportional to the velocity of approach of the vessels, read between the ordinates of these points. This distance may be confirmed or checked by a third observation being also plotted in the danger line. So far the assumption is that collision is threatened, and, as we have seen, at a considerable distance the rate of approach will differ but little from the danger rate if the value of α is small.

The rest is obvious. As distance after distance comes in they are plotted to their appropriate ordinates as read upon the T-square and to the abscissæ given by the first two or three observations plotted on the danger line. If now collision is coming, these points will continue to lie on the danger line. Otherwise the points at the near distances will lie above the danger line, following the course of such curves as are shown in fig. 3. The departure of the points from the danger line indicates safety. If observations are spaced half a minute apart it would be desirable that an assistant operator should plot the results as they come in.

The little trouble of plotting the distances, as described above, may be eliminated by use of a chronograph designed for the purpose. Here the diagonal of the danger curve describes a spiral on a cylinder driven by clockwork. A pen travels parallel with the axis of the cylinder. Its motion is uniform and describes the length of the cylinder in 12 seconds. It marks the surface of the drum when the operator makes a contact on hearing the bell. After completing its course it returns to the base and starts afresh 18 seconds later. The travelling pen replaces the stop-watch.

The first mark is adjusted to the diagonal line by setting the cylinder round on its axis. The second mark is also so adjusted. The cylinder is now started into motion and automatically rotates through the angular separation of these marks just before the pen starts on its journey. The operator, after the first adjustment of the angular displacement of the cylinder, has only to make contact at each bell stroke. Many variants of such a machine

may be suggested. It is not, in fact, necessary to plot the observations. It is only essentially necessary to ascertain if the distances as given by the earlier observations are maintained. Hence any mechanical or optical means which will submit these distances for comparison with those given by subsequent observations will afford the sailor all that he requires.

If collision seems threatened some rough indication of the bearing of B is finally necessary in order to ascertain which vessel must give way. This may be readily effected by radio-goniometer, using the wireless dots emitted by B or in many cases by aërial sound signal. The navigator on A knows now in what direction B is approaching and this enables him to decide whether action is incumbent on him or not.

Throughout these operations proceeding on A, similar observations are proceeding upon B. A is emitting synchronous signals timed so as not to clash with those emitted by B. Thus they would be displaced $\frac{1}{4}$ minute upon those of the other ship. If necessary a code signal by wireless might pass between the vessels, regulating this procedure.

PART II.

(Received June 6, 1918.)

For the practical application of the method referred to above, it is desirable to so order the emission of the signals that the time interval between the arrival of the signals should be capable of observation with the utmost accuracy attainable. To this end the listener must be placed in a state of preparedness for the coming signal. Hence the important signal should be a certain one of a series. Thus the important synchronised radio dot might be the third of an equally spaced series of dots, and the bell-stroke, or oscillator blast, the third of three equally spaced signals, or three successive synchronised radio and submarine signals might be issued, the third being preferably taken for observation. The observer gets into stride by counting up to the important signal.

An instrument whereby the signals may be emitted and received is shown in fig. 4. We are looking at the dial of an accurate clock, having one central hand, which completes a revolution in nearly 15 seconds. This assumes that a ship may be under observation 12 miles off, and that sound in sea-water travels 1 sea-mile in 1.24 seconds. (Good experiments on this important datum, made with such sound-producing instruments as would be used, are to be desired.) The complete rotation of the hand, therefore, occurs in the time taken for sound to travel between vessels 12 miles apart. A smaller hand records the number of revolutions.

The clock can be started and stopped by electric contacts. At the outer extremity of the central hand is attached a stamp capable of printing a fine

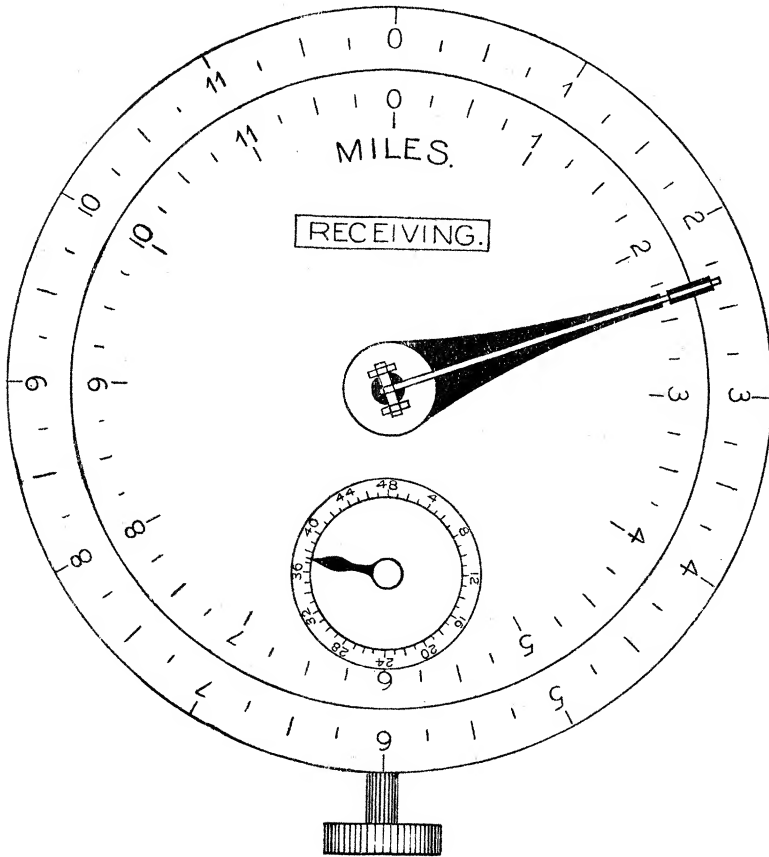


FIG. 4.

radial line about $\frac{1}{2}$ cm. long on the enamelled dial or face of the clock. This stamp comes into operation on making a contact. As it is necessary to secure a sharp line, and as the extremity of the hand may be moving at the rate of, say, 3 cm. per second, the action must be brief. To facilitate good definition, the stamp, which I assume charged with aniline ink, sweeps very close above the surface of the dial. It may, moreover, be hinged where it meets the supporting hand, so that, during the instant of contact, it is not dragged laterally, but is slightly deflected from the perpendicular. The hinge axis is, of course, parallel with the radius of the dial.

The outer rim of the dial can be rotated smoothly round the inner part on turning the thumb-screw in front. A notch and spring normally retain it in its position of coincidence with the central dial. The radial lines struck by

the stamp cross the meeting line of the outer and inner dials, about one-half the line appearing on each dial. Both dials are numbered in miles as shown.

It will now be understood that this machine acts as a chronograph. Upon hearing the third wireless dot the operator by making contact starts the hand into rotation and then listens for the submarine sound signals. When these arrive he again makes contact at the third sound signal. The stamp then instantly strikes the radial line on the dial. For better distinction it might be well to have the permanent subdivisions on the dial in red and the signal records in black or purple. The hand continues its uniform rotation and begins a second rotation. About 15 seconds have now elapsed.

During the second period of 15 seconds sound signals are travelling from ship A to ship B. The clock begins to make radio-contacts some time before the hand completes the first rotation. First these contacts spell out the characteristic code signal proper to the vessel; then there are three radio dots in succession and the third dot is made just as the hand completes the first rotation, at the instant on which it is crossing the zero line. Three submarine bell strokes (or oscillator blasts) are made coincident with the three radio dots. Thus, the third submarine signal is emitted along with the third radio dot. The third dot and the third submarine signal are the signals which will be used on the other ship, B, for finding distance. While the hand of the clock is describing its second revolution the semaphore signal shown on the dial and carrying the word "receiving" is replaced by one with the word "emitting" upon it. During this second rotation the operator on the other ship, B, is taking in the signals sent out by A.

During the third revolution the operator on A has only to wait for the sound signal to come in and to again make contact in order to secure the record of the second distance. He now has before him two records of distance. If the second shows a greater distance than the first, the other ship is receding and further observations are unnecessary.

If, however, the second distance is less than the first, B is approaching, and it is now the business of the observer to watch the rate of approach with a view to finding whether the rate is constant or diminishing, as explained above. And here is where the use of the rotating outer dial comes in. The operator can at any time compare the earlier differences of distance shown by successive readings with the later differences. If the lines are sharp the comparison is a sensitive one. He brings one of the earlier lines, *i.e.* that part of it which is on the outer dial, into coincidence with a later line on the inner dial. The ships may be five miles apart when the earlier line was struck. He places the outer line *in directum* with a line on the inner dial which was struck when the ships were, say, two miles apart. Is the next

succeeding line on the outer dial now coincident with the next succeeding line on the inner dial? This comparison may be readily made in the time interval—about half a minute—between the bell strokes. If there is coincidence the danger of collision still threatens and further observations must be made. The outer dial is returned to its original or zero position. Observations can be carried on up to a point when it is no longer safe to defer attending to the rule of the road. This point will depend on the rate of approach of the vessels. The bearing of the other ship may now be got roughly by taking in the radio dots on the radio-goniometer or by aerial sound-signal and the procedure as regards altering course or holding on regulated accordingly. At the conclusion of the observations the aniline ink marks are removed from the dial by a cloth or sponge.

In this system the duties of the operator during a series of observations are confined to taking in the sound signals as they arrive, and to examining these for signs of diminished rate of approach. The first takes but an instant to perform. The observer may, therefore, give a great part of his attention to the latter. There is no need for him to attend to the wireless dots once the clock has been synchronised with that on the other vessel. A small error in this synchronisation is of little importance. It merely increases or diminishes by a little the distances read throughout. The important question as to whether there is a diminished rate of approach or whether this remains constant is unaffected. Nor is any extraordinary accuracy of time-keeping required of the clock. An accuracy of one minute in the month is easily attained in watches and clocks. This would mean a + or — error of less than 1/100 of a second during the five or six minutes in which the observations were in progress.

There can be no overlapping or confusion of signals controlled in the manner suggested. The synchronisation of clocks would be effected by attention to simple rules of procedure. When fog, etc., comes on, every ship must set in motion the apparatus described above. This means that every 30 seconds ships A and B are sending out their characteristic code signals, followed by three successive synchronised radio dots and bell-strokes. Now, when A hears B it is the business of the operator on A to secure synchronisation, but as B may have already secured this, he begins by observing his clock when the radio dots of B are coming in. If the third radio dot is received when the hand of his clock is just at zero, he knows that B has already synchronised the clocks, and he need not interfere. If, however, he observes that there is not this coincidence, or that the emission of his signals are obviously out of symmetry with those coming in, he sets his clock to synchronise with the signals from B, as already described.

The problem presented by the presence of three vessels in an area of mutual audition is deserving of consideration, although it is doubtless one of rare occurrence on the high seas. It is, of course, quite possible for all three vessels to hold their courses and speeds, each ship observing the distance of two ships and emitting her own signal. It would be easy to do this, using a modified form of the chronograph described above. But, in general, it may be assumed that A and B are already synchronised before C comes in, and they may have reached a critical stage in their observations, when interruption might create confusion. On the whole, therefore, the safest course would seem to involve that C keep out till A and B are clear. This would mean that C emits no synchronised signals, although she might avail herself of those proceeding from A and B. The onus of keeping clear would fall on C, and she must slow down if requisite. In general, she will early find herself clear of A or B, and need only attend to preserving a certain specified radius of safety respecting one of these vessels. She will assist her navigation by taking in the radio signals of A and B on her radio-goniometer. It would be allowable for her to emit the usual aërial sound signals.

The fundamental condition of safety will always involve that each ship preserve a certain radius of isolation or radius of safety, within which no other vessel must enter. Taking the dimensions and speeds of modern vessels into account, $\frac{1}{2}$ mile would not be too great a radius; 1 mile would seem to be better. But many points arise in connection with this subject which can only be handled by experienced sailors, and this is one of them.
